Science of the Total Environment 576 (2017) 817–828

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Contextual and interdependent causes of climate change adaptation barriers: Insights from water management institutions in Himachal Pradesh, India

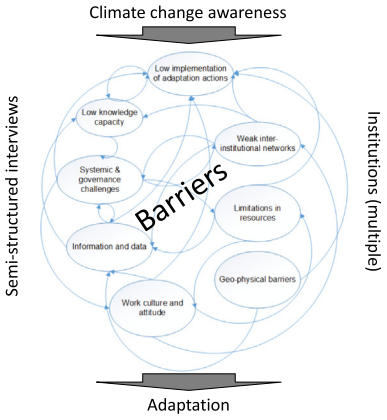
Adani Azhoni [a], Ian Holman [a,*], Simon Jude [b]

[a] Cranfield Water Science Institute, Cranfield University, Cranfield MK43 0AL, UK
[b] Cranfield Institute for Resilient Futures, Cranfield University, Cranfield MK43 0AL, UK

HIGHLIGHTS

- Investigates the poorly studied underlying causes of adaptation barriers
- Semi-structured interviews in Himachal Pradesh, India reveal complex interconnected barriers
- Low knowledge capacity compounds resource, information and data barriers
- Trust deficits, power struggles, and institutional fragmentation underpin observed barriers
- Systemic approach to barriers needs to consider socio-economic and institutional contexts

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 3 June 2016
Received in revised form 17 October 2016
Accepted 19 October 2016
Available online xxxx

Editor: D. Barcelo

Keywords:
Adaptation
Barriers
Climate change
Institutions
India
Water

ABSTRACT

Research on adaptation barriers is increasing as the need for climate change adaptation becomes evident. However, empirical studies regarding the emergence, causes and sustenance of adaptation barriers remain limited. This research identifies key contextual causes of adaptation barriers in water institutions in the mountainous Himalayan state of Himachal Pradesh in northern India. Semi-structured interviews were carried out with representatives from twenty-six key governmental, non-governmental, academic and research institutions in the State with responsibilities spanning domestic water supply, irrigation and hydropower generation, environmental monitoring and research. It identified low knowledge capacity and resources, policy implementation gaps, normative attitudes, and unavailability and inaccessibility of data and information compounded with weak inter-institutional networks as key adaptation barriers. Although these barriers are similar to those reported elsewhere, they have important locally-contextual root causes. For instance, inadequate resources result from fragmented resources allocation due to competing developmental priorities and the desire of the political leadership to please diverse electors, rather than climate scepticism. The identified individual barriers are found to be highly inter-dependent and closely intertwined which enables the identification of leverage points for interventions to maximise barrier removal. For instance, breaking down key barriers hindering accessibility to data and information, which are shaped by systemic bureaucracies and cultural attitudes, will involve attitudinal change through sensitisation to the importance of accurate and accessible data and information and the building

* Corresponding author.
E-mail address: i.holman@cranfield.ac.uk (I. Holman).

http://dx.doi.org/10.1016/j.scitotenv.2016.10.151
0048-9697/

trust between different actors, in addition to institutional structural changes through legislation and inter-institutional agreements. Approaching barriers as a system of contextually interconnected cultural, systemic, geographical and political underlying factors enriches the understanding of adaptation enablers, thereby contributing to achieving a better adapted society.

1. Introduction

Climate change is expected to be experienced most through water (IPCC, 2012; Jiménez Cisneros et al., 2014). Water institutions at all levels will need to adapt to climate change (IPCC, 2014), and hence, many national and regional governments are now developing adaptation policies and plans (Krysanova et al., 2010; Mertz et al., 2009; Pittock, 2011; Preston et al., 2010). However, many factors can stop, delay or divert even well-planned adaptation strategies (Preston et al., 2010; Moser and Ekstrom, 2010) if they are not adequately identified and addressed (Eisenack et al., 2014).

Barriers to adaptation has been defined from different aspects with terms such as limits (Dow et al., 2013), challenges (Fünfgeld, 2010), obstacles (Bedsworth and Hanak, 2010), and constraints (Klein et al., 2014) often being used synonymously. Klein et al. (2014) differentiated adaptation constraints from limits by defining the former as 'factors that make it harder to plan and implement adaptation actions' and the latter, following Adger et al. (2009); Dow et al. (2013); Islam et al. (2014), as 'the point at which an actor's objectives or system's needs cannot be secured from intolerable risks through adaptive actions'. On the other hand, Moser and Ekstrom (2010) defined barriers positively as 'obstacles that can be overcome with concerted effort, creative management, change of thinking, prioritization, and related shifts in resources, land uses, institutions, etc.'. Hence, a consensus is emerging among researchers to use 'limit' to refer to 'the threshold beyond which existing adaptation efforts cannot overcome it' (IPCC, 2014) and studies on adaptation 'barrier' commonly focus on the challenges emerging from socio-economic and institutional factors (Barnett et al., 2015; Biesbroek et al., 2014a; Eisenack et al., 2014; Oberlack, 2016). Adger et al. (2009), argued that limits (and barriers) are endogenous and emerge from 'inside' society and hence contingent upon ethics, attitudes to risks, knowledge and cultural values depending on the ultimate goals of adaptation. Therefore, Eisenack et al. (2014) stressed the contextual nature of adaptation barriers and defined them as 'an impediment to specified adaptations for specified actors in their given context that arise from a condition or set of conditions'. Hence, barriers can be 'valued differently by different actors, and can, in principle, be reduced or overcome' (Eisenack et al., 2014). This means barriers are contingent upon the attributes of adaptation, actors, and their context.

Moser and Ekstrom (2010) propose that resolving barriers, rather than skipping phases of the decision process, will ultimately prove beneficial for the decision outcome. This requires exposing and questioning the factors that stop, divert or delay institutions from effectively adapting (Berkhout, 2012), preventing them from becoming limits to adaptation (Barnett et al., 2015). If barriers are 'factors that make it harder to plan and implement adaptation actions' (Klein et al., 2014), then lack of knowledge, technology, financial resources, and political will are important barriers which many other studies have identified. For example, Engle (2012) pointed out the lack of financial resources, infrastructure, focus on short-term issues and competing developmental priorities as important barriers, while Amundsen et al. (2010) and Baker et al. (2012) pointed out legislation issues such as unclear roles of actors and lack of consistent and clear policy guidelines from state and federal governments based on specific case studies. However, although such generic barriers have been identified, the circumstances in which these barriers arise and persist are poorly understood (Biesbroek et al., 2014b) and require explaining (Eisenack et al., 2014). The relevance of this paper arises from the need to better understand why such barriers emerge and persist and how they are interrelated with other barriers and socio-cultural and politico-economic factors.

The ability of water management institutions to adapt to the new and changing climate depends on how decision makers within those institutions perceive and interpret the potential risks (Berkhout, 2012). However, public agencies, such as water supply departments, are also shaped by the constraints of external factors such as laws, regulations and socio-cultural-politico-economic context in which they operate (Pahl-Wostl, 2009; Roggero, 2015). Moreover, institutions operating in different sectors; from environment to irrigation to hydropower and domestic supply have both distinct and complementary roles in developing and implementing adaptation strategies (Adger et al., 2005; Fidelman et al., 2013; Nalau et al., 2015). This is particularly so for adapting water management to climate change from basin level management organisations to regional and national governments and local municipal bodies (Bisaro et al., 2010; Finger et al., 2006; Lebel and Garden, 2008; Mollinga et al., 2006; Pittock, 2011; Wilby and Wood, 2012). Barriers emerging from poor coordination between and within institutions responsible for planning and implementing adaptation strategies are particularly prominent in developing economies (Spires et al., 2014). But knowledge on barriers for institutions to adapt, particularly in developing economies, remains scattered and barriers emerging from socio-economic, political and cultural factors are poorly understood (Shackleton et al., 2015). Studies that seek to expound the underlying causes of barriers and the interdependences between them are lacking (Eisenack et al., 2014), due to which designing successful adaptation strategies remain challenging (Oberlack, 2016). Although there is a growing research interest on adaptation barriers in general, research on barriers for institutions to adapt is relatively minimal (Biesbroek et al., 2013). This study aims to address this key knowledge gap by

Box 1
Highlights of interview questions.

a) Views on climate change and likely impacts for Himachal
b) Adaptation strategies adopted or initiated
c) Involvement in the State Strategy and Action Plan on climate change
d) Guidelines and instructions received regarding climate change adaptation
e) Key partner institutions and reasons and challenges
f) Perceived role of institutions operating at different scales: Federal and State
g) Suggestions for adaptation enablers including for improved coordination and overcoming barriers and opportunities

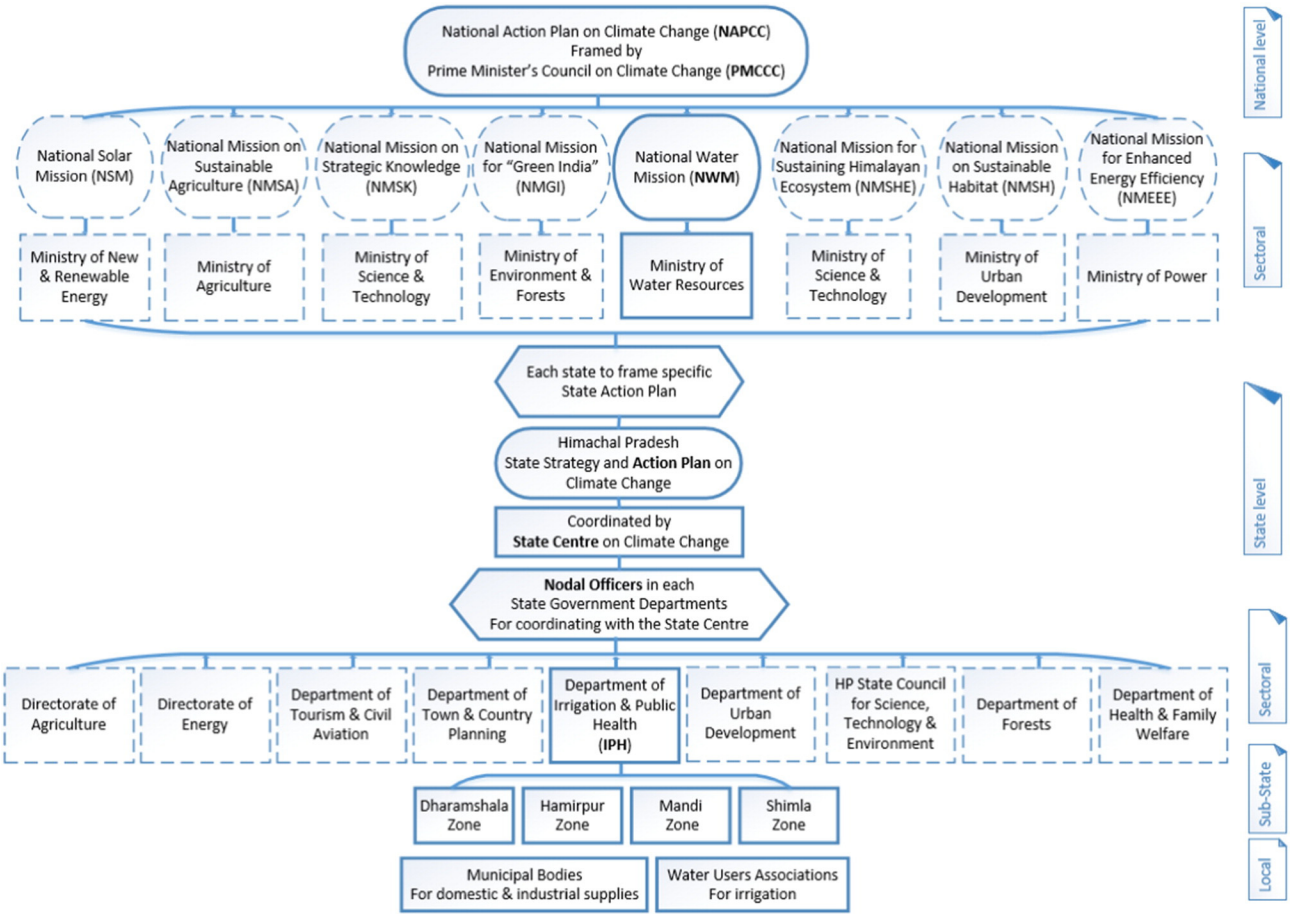


Fig. 1. Schematic diagram of the top-down institutional and policy hierarchy for climate change adaptation. Institutions more relevant for water are emphasised with full boxes.

identifying and expounding the underlying contextual causes of adaptation barriers within regional and local water institutions in a developing economy (India).

1.1. Context: water institutions in Himachal Pradesh, India

The north-western Himalayan state of Himachal Pradesh has high sensitivity to climate change (Brenkert and Malone, 2005; Mall et al., 2006), due to the importance of irrigation and hydropower from glacier-fed rivers (Jaswal et al., 2015; Rana et al., 2014). The State established the State Centre on Climate Change (henceforth, the State Centre) and formulated the State Strategy and Action Plan on Climate Change (henceforth, the State Action Plan) (DEST-HP, 2012) to address the challenges (Fig. 1). The Action Plan is designed to align with the eight National Missions (Fig. 1) which the Government of India initiated under the National Action Plan on Climate Change (NAPCC) (PMCCC, 2008). Nodal Officers are appointed in each of the nine State Government Departments to co-ordinate the delivery of the Action Plan with the State Centre and information dissemination. A schematic diagram of the top-down institutional and policy hierarchy for implementation of the NAPCC in India is shown in Fig. 1.

2. Methods

Since perceptions of key actors play a crucial role in climate change adaptation (Eisenack and Stecker, 2012), this study used a qualitative approach. A semi-structured interview template (highlights of questions in Box 1 and detailed questions in Appendix A) was framed to empirically assess the contextual barriers for institutions to adapt water management. It was based on a literature review, a previous study conducted with the institutions operating at the national level (under review) and refined through a pilot interview. Interviewees within 26 key institutions in Himachal Pradesh (henceforth, the State) (Fig. 2) were identified based on their work portfolio or by recommendation of other respondents.

Interviewees were all mid-level officials or above, and represented nine State Government (SG) departments (shown in Fig. 1), Regional Offices of two Central Government agencies located in the State (CG), three research and academic institutions (RA), six non-governmental and consulting organisations (NG) and the four zones (Figs. 1 and 2) within the State Irrigation and Public Health Department (IPH). All Nodal Officers (for the State Action Plan) were interviewed, except in the Department of Health and Family Welfare. More detailed assessment was targeted on IPH as it is the primary institution for water management in the State. Respondents were coded by these acronyms along with a numerical figure to anonymise yet retain traceability.

Interviews were conducted in January and February 2015, lasting for an average of approximately 40 min (range - five to 80 min). They were conducted in English, except in two where there was a mixture of Hindi and English and audio recorded, apart from three where permission was not granted.

Employing rigorous method of content analysis, which consists of classifying, organising and examining the data to make inferences about the patterns (Graneheim and Lundman, 2004; Strijbos et al., 2006), the interview discourses were transcribed verbatim, except the Hindi words which were translated into English while transcribing. They were analysed with the aim of understanding: a) perceptions of climate change impacts on water, b) actions being initiated, and c)

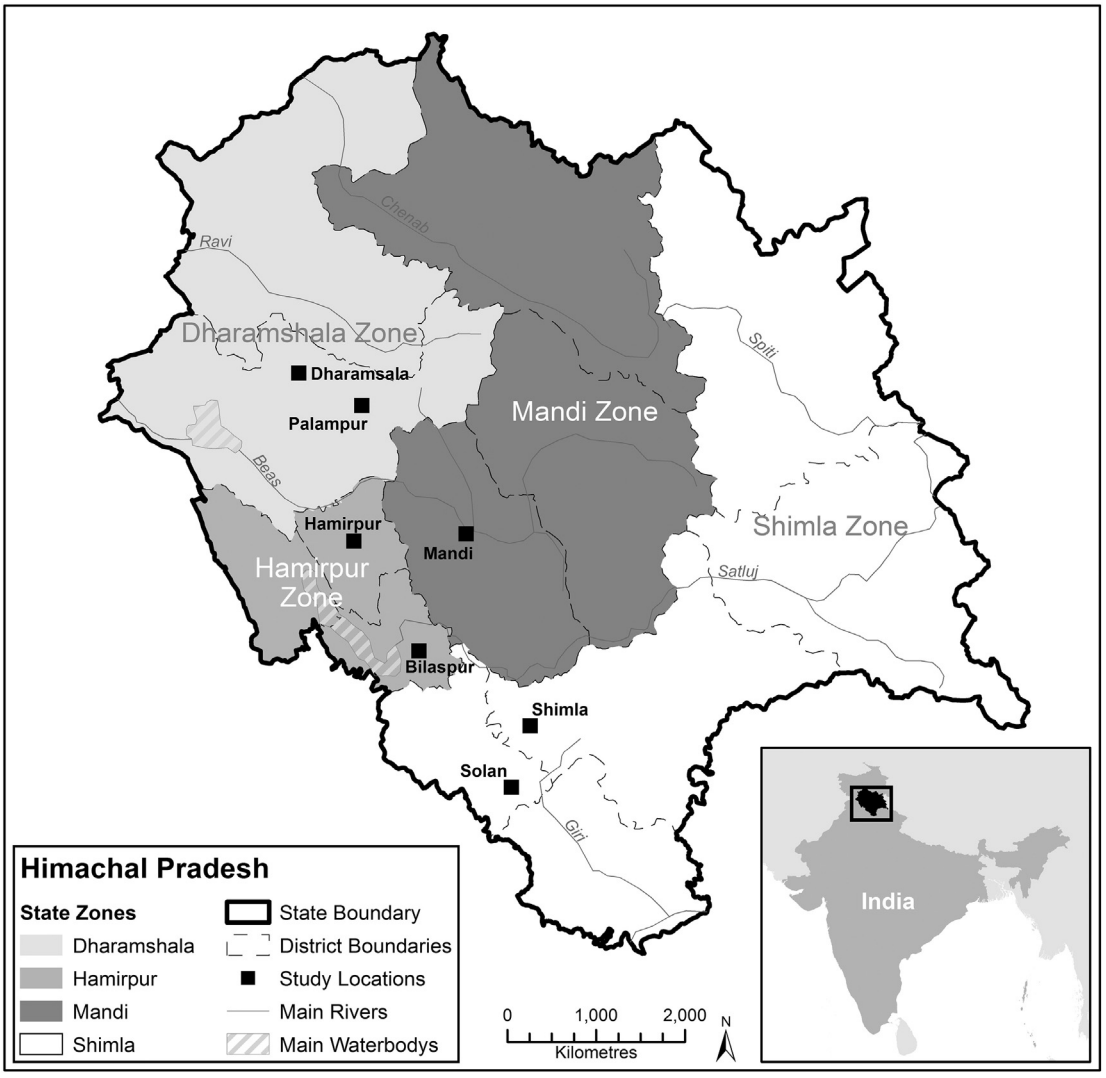


Fig. 2. The study location: Himachal Pradesh.

barriers and challenges of adaptation. Barriers of adaptation were identified primarily by asking respondents the challenges their institutions face to adopt or implement adaptation strategies identified by the State Action Plan on Climate Change. These were corroborated or contrasted with the responses from other institutions. Causes of adaptation barriers were identified based on follow-up questions but also by connecting the various responses. Enabling factors were identified from the suggestions of the respondents to subsequent questions of what they perceived as ways to overcome the challenges. These barriers, underlying causes, and suggestions and aspirations to overcome the barriers also emerged during the interview while discussing the challenges. Responses corroborating or negating a particular barrier were extracted and arranged systematically using qualitative analysis software *NVivo 10* (Richards, 1999). As is conventional within grounded theory literature (Mills et al., 2006; Saldana, 2009; Tang et al., 2013), categories and sub-categories are marked out during coding, and new categories created which are regrouped or renamed iteratively (Saldana, 2009) so that the coding structure evolves. Data collection and analysis went hand-in-hand and the procedure is not linear or sequential as is conventional in grounded theory (Bryant, 2014). Hence, it was both reflexive and iterative. As such, the first draft was coded with long quotes to retain the context of the response, with redundant words trimmed off in the successive iterations. This iterative process ensured that the insights were drawn from the data and guided by the state of the art in the literature.

3. Findings and analysis

The findings are presented by first connecting the climate change risk perceptions of the respondents and existing adaptation actions to the State Strategy and Action Plan. Then the most commonly cited barriers are analysed to understand their underlying causes. Further, the relationships between the different barriers are analysed to identify opportunities for leveraging adaptation. Direct quotations are provided to illustrate the findings and are intentionally extracted from diverse respondents to bring out the richness and the prevalence of such barriers across different institutions.

3.1. Risk perceptions and current adaptation initiatives

There is a consensus among the respondents that a changing climate is manifest in the depletion of water sources in the State and late arrival of winter snow, for example "*Climate change indicators are very clear over here*" (RA05), although additional factors contributing to the depletion of water sources, including land use change, deforestation, mining, and increased water use were also identified.

Interviewees identified numerous water management adaptation activities being undertaken by their department. These included climate change impact research, provision of farmer advice, the creation of a Hydrology Division within IPH to collect hydrological data, long term trend analysis and preferring larger and perennial sources for new domestic

Table 1
Barriers commonly cited by interview respondents. '*N*' indicates the number of respondents whose transcripts contain the respective code.

Codes	Description	Illustrative example quotes
Knowledge capacity $N = 13$	Inability to contextualise the potential impacts and identify suitable adaptation strategies	"*Technically, we do not have experts because climate change needs experts*." (IP08) "*Climatic change will be beyond the comprehension of many of us*." (IP03) "*We are not competent or knowledgeable*." (SG14)
Implementation gaps $N = 13$	Poor implementation of policies that enhances adaptation including data collection and monitoring	"*I can come out with very good plans and very good documents but somebody else has to implement. Himachal at the moment is not equipped with that level of competence*." (SG09) "*See there is no connect between the documentation bit and the ground level bit*." (NG18) "*The research is being done … but who is the implementing authority? Who is the user of those technologies*?" (RA24)
Weak inter-institutional networks $N = 12$	Poor coordination between institutions with overlapping, similar or related activities.	"*There is no linkage between various departments. What Forest Department is doing, Water Resources Department does not know and vice-versa*." (RA22) "*There is no coordination between the line departments. Absolutely no coordination. May be for celebration sake they will come together*." (NG26)
Systemic and governance $N = 9$	Bureaucratic and lengthy procedures of decision making, weak monitoring and follow-up mechanisms to ensure the implementation and accountability.	"*All the departments have appointed the nodal officers but later on if we ask them he is either transferred or not there*." (SG09) "*In the system you have so many bottlenecks. That, at the end of the day you'll say, just forget it*." (NG18) "*As far as climate change is concerned, governance … is one of the big challenges which has not been addressed, particularly in Himalayan region*." (RA22)
Data availability and accessibility $N = 6$	Lack of crucial primary data and information or inaccessibility or inapplicability of the existing data.	"*We don't have a very robust data. We are still groping in the dark*." (SG11) "*We don't have proper data base then all these things are hypothetical*." (IP01)
Resources limitation $N = 6$	Barriers due to lack of human, financial, technological or natural resources.	"*The State Centre on Climate Change for the want of funds couldn't do good projects*." (RA24) "*Give me other supporting staffs. How can I be the only to collect data from field, monitor and analyse*?" (NG25)
Normative attitude $N = 6$	Complacency, apathy and casual attitudes towards risks.	"*…because the concerned person is not concerned. The person attends the meetings and conferences but he goes up to only that level*." (NG18) "*It is a behavioural attitude. The departments which are supposed to collect basic data are not able to do it*." (NG25) "*Lack of professionalism and of accountability*." (NG25)
Local geographical factors $N = 6$	Difficulties due to the natural physical conditions such as steep mountains.	"*Whatever happens to the national policy is just copy and pasted to the state policy. The State specificity do not really come up and that is an issue*." (NG19) "*We will have to devise numerous models in order to implement those strategies*." (SG09)

water supply projects - "*…the new policy is that instead of having the present small source, we are looking for… bigger sources where we have a good level of confidence that the sources are going to survive for twenty or thirty years*" (IP06). However, many of these activities are not specifically named climate change adaptation, so that "*so far as climate change is concerned, the department is not doing anything*" (IP03) – although "*now this sustainability word is gaining importance over here that whatever we plan should be a sustainable one*" (IP07).

Initiatives such as the compulsory installation of rainwater harvesting structures in every new (Government) building and rejuvenation of catchments through watershed management are being introduced in the State Action Plan. However, some respondents are sceptical: "*hardly ten percent of the government buildings will have such structures*" (NG25). When asked how they are going to implement the Action Plan, a respondent stated that "*the Strategic document… is not a legislation… just a recommendation. It is voluntary upon all institutions whether they adopt it or not. … we don't have any implementing authority*" (RA24). Similarly, another respondent dismissed it, saying it is "*more of a wish list of this should be done, that should be done with very little practical aspects*" (SG11) and lacked actions and responsibilities for implementation. Respondents also often used "should" rather than "is" when asked about the activities of their institutions to address climate change impacts; implying that many of the aspirations are yet to turn into adaptation actions.

3.2. Key generic barriers informed by the respondents

The barriers most commonly mentioned by the respondents (Table 1) include limited knowledge, gaps in implementation of policies, weak inter-institutional networks, unavailability of data and information, limited financial and human resources, normative attitudes, and local geographical challenges. Attitudes such as the assumption that climate change is a future distant challenge, is the responsibility of another institution, or the complacency that we can 'muddle through', apathy and the casual approach towards climate risks are categorised under 'normative attitude' here in Table 1. On the other hand, governance and management challenges emerging from the 'normal' bureaucratic procedures or the lack of follow-up mechanisms to cross-check and ensure the implementation of policies are classified here collectively under 'systemic and governance' barriers while 'local geographical factors' refer to the challenges due to the mountainous terrain of the State. The number of references made by various respondents about a particular issue is indicated with "N" (Table 1) to illustrate how often respondents cited that particular issue giving an indication of how frequently the barrier is encountered, experienced or identified. Only representative quotations are provided in the table as the same issue is repetitively mentioned by various respondents from different perspectives. The most commonly cited barrier may not be the most important barrier (within or between institutions) but merely the most easily identifiable.

The lack of knowledge capacity to plan suitable adaptation strategies is compounded by the inherent uncertainties in the likely impacts of climate change and the long time scale involved:

> "*Adaptation… very easily we use this word. But how do we adapt? Solutions for adaptations are still awaited from scientists or planners. So we need to work on adaptive research. How to adapt to a particular problem? In that too, because this problem is not scale neutral, solutions are local level. And adaptation methods are also different at landscapes, crop, peoples, societies and communities. So one solution cannot be*

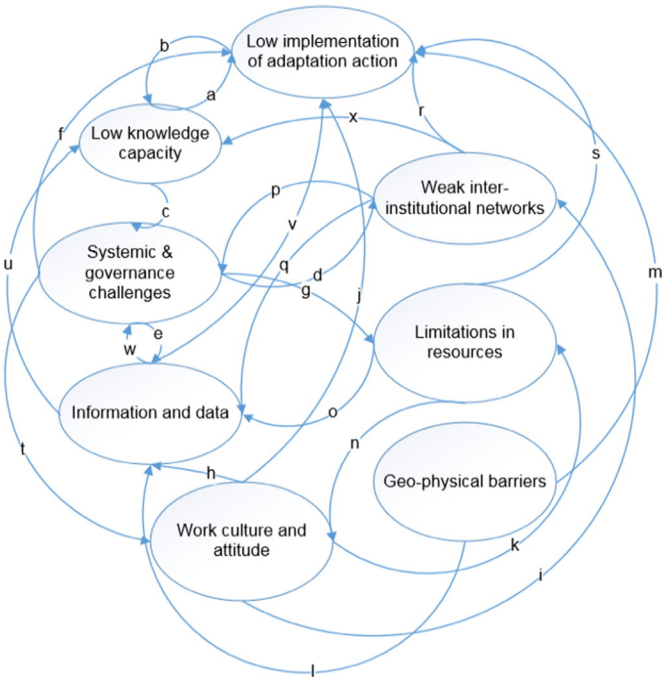


Fig. 3. Conceptualisation of barrier inter-dependencies for climate change adaptation within water management institutions in Himachal Pradesh, India. The causes of interrelationships between the barriers are indicated with letters: a, b, c, … and empirical evidence of these is presented in Table 2.

remedy for all. There is a lack of real adaptation methodologies through which people should adapt." (RA24).

Inadequate implementation of the existing (general) policies is closely intertwined with the lack of knowledge capacity alongside normative behaviours discussed later. Weak inter-institutional networks between stakeholder institutions were acknowledged by respondents from non-governmental, governmental, and research institutions. This is despite the State Centre being created to act as the nodal institution for coordinating climate change related activities. The weak inter-institutional networks are compounded by systemic and institutional structures, alongside normative behaviours and working culture, including the routine transfer of government officials and the bureaucratic processes of routing every communication through the Heads of the Department.

Accessibility to existing data collected by Central Government agencies and the lack of data from remote locations was a key barrier stressed by both State Government agencies and non-governmental and research institutions. Respondents linked these barriers to the long bureaucratic protocols and attitudes of officials holding such data, which are discussed later, the difficulties posed by the State's geography and inadequacy of technological infrastructure.

3.3. Underlying causes and interconnectedness of barriers

Many of the barriers described above and their underlying causes are clearly interconnected. Fig. 3 illustrates these interconnections and inter-dependencies using the empirical evidence from the interviews summarised in Table 2. Commonly mentioned barriers including inadequate knowledge (Table 2: a), ineffective implementation of policies (Table 2: b) and weak inter-institutional network (Table 2: r), are clearly shown to be interdependent. For example, the lack of knowledge capacity leads to inadequate identification of potential risks, which not only leads to indifferent attitude towards potential climate change risks but also limitations in planning and design of adequate strategies, policies, and guidelines and inadequate resource allocation for addressing those risks (Table 2: a, b and c). Table 2 also summarises interviewees' suggestions for key enablers to reduce or overcome these barriers. Analysis of the underlying causes of the barriers are summarised below. Although the causes of these barriers are cross-cutting and inter-dependent, they have been categorised into the following subsections to simplify the analysis and presentation of the findings.

3.3.1. Socio-cultural attitude, complacency, and organisational normative behaviours

Awareness that climate is changing is insufficient to change people's attitude and normative behaviours, such as the tendency to believe in the ability to 'muddling through', casual attitude towards risks, and shrugging off responsibilities. Respondents reported the existence of complacency among the general public "*… here we still think that water is in abundance. … Until and unless we realize that this is also limited … we won't be able to cope up…*" (IP06), which is the reason "*it is very difficult to sell adaptation … and* [difficult to convince] *why it is important for them*" (NG19). As a consequence "*when you talk about adaptation not many people are working towards adaptation and they don't have a clue*" (NG18). State water institutions are more concerned with meeting the current daily demands than investing time, effort and resources in assessing and planning responses to future long term impacts: "*But to understand the problems which are of long term nature and have some time and money to redefine their priorities in terms of the future events of the climate change, that is still lacking*" (RA24). This short-termism is compounded by an attitude that climate change adaptation is the work of specialists or 'experts', providing a rationale for a lack of proactive actions or sense of responsibility to act on it: "*Climate change is something not all people can understand easily. Only educated people have little knowledge about climate change. It is an elite class question not a grassroots*" (SG15).

Likewise, some officials absolve themselves of responsibilities by implying that the Department of Environment, Science and Technology (DEST) ought to carry out all activities related to climate change: "*The department which is supposed to think is doing something…. Nothing can be done. We can't do anything. We only build buildings*" (SG16). This lack of interest was corroborated by a respondent from DEST: "*this overall subject* [climate change and environmental conservation in general] *is perceived usually as antidevelopment…. So at the outset they are indifferent. Gradually we are reaching and telling them it is the responsibility of all of us*". Hence, a non-governmental organization respondent blames the apathy of government institutions: "*They are very aware broadly but they don't have the implementation attitude*" (NG26). Another respondent pointed out the disconnection between awareness, policy making and implementation: "*Government awareness is there. … Lots of government energy, money and time is spent on talking about the climate change. But how far this has transformed into action is a different thing*" (IP06). A respondent sums this up:

> "*It is a behavioural attitude. The departments which are supposed to collect basic data are not able to do it. Therefore all these plans and strategies are pretty much hypothetical. Lack of commitment, lack of manpower and lack of willingness to shift to better technological solutions*" (NG25).

This respondent goes on to add that the Government agencies "*Lack* [of] *professionalism and* [of] *accountability. Communicating with these departments is terrible*" (NG25). The barriers related to data accessibility, weak inter-institutional networks and lack of motivation discussed in the subsequent sections also arise out of normative behaviours and socio-cultural attitudes (Table 2: h). As one interviewee put it: "*…nobody wants to share the data… everybody who has the data he is the boss*" (IP06).

3.3.2. Leadership and motivation

The Himachal Pradesh State Government leadership initially showed greater interest in climate change issues compared to many

Table 2
Causes and relations of barriers and suggestions from respondents for overcoming.

Causes and interconnections	Quotes from interview	Implications	Suggested enablers
a. Low knowledge capacity leads to low implementation	"*The major hurdle is that the impacts is of such a general nature that we cannot take specific action*" (IP08)	Inability to contextualise the challenges and frame specific actions	"*We need to know the magnitude of the problem… reliable… data and … modelling* [that] *can tell us precisely what is going to happen and then some practical easy, quick solutions. Doesn't need to be highly technical….*" (SG11)
b. Low implementation of adaptation actions leads to low knowledge capacity	"*We always talk adapt, adapt, adapt but what to adapt? Who has done it?*" (RA24) "*We will only know these challenges when we are in field*" (SG13)	Adaptation being an iterative process, non-implementation of adaptation strategies leads to loss of learning opportunities.	"*Basically first is capacity building is must. It has to be an ongoing… process.*" (SG11)
c. Low knowledge capacity leads to systemic and governance failures	"*As far as climate change is concerned, governance… is one of the big challenges which has not been addressed….*" (RI22)	Inability to design institutional structures and mechanisms due to inadequate knowledge	"*We need to scale it down… to make* [local government agencies] *understand… long term impacts*" (RA24)
d. Systemic and governance deficiencies leads to weak inter-institutional networks between different institutions & sectors	"*What Forest Department is doing, Water Resources Department does not know and vice-versa. …policy … should be holistic….*" (RA22)	The current institutional structure is not able to adequately deliver effective coordination between different agencies	"*We must have a central agency even at district level*" (IP03) "*should set up a nodal agency which can coordinate with different organisations*" (IP02)
e. Systemic and governance deficiencies leads to unavailability of information and data	"*Research work is not a priority. We do not want to invest in these things because the results are not discernible*" (IP08)	More focus on the immediate developmental needs than investing for long term needs	"*Research wings should be opened in each and every organisations, and people who are interested in research and development activities should be encouraged*" (IP02)
f. Systemic and governance challenges leads to low implementation of adaptation actions	"*…we plan nicely on paper, but as far as implementation is concerned we lack*" (IP02)	Inadequate monitoring and follow-up mechanisms	"*We must establish such mechanisms that can deliver whatever we plan*" (IP02)
g. Systemic and governance challenges leads to resources limitations	"*The defect in planning* [fragmentation of financial resources] *not only implementation. …So none of the project is complete*" (IP03) "*So it's a repetition of what A has done B is also doing the same thing*" (NG18)	Inadequacies in resources allocation	"*At every district level you should have an agency, …whatever proposals are there for water harvesting. That agency should approve that*" (IP03) "*the multiplicity of these departments should be avoided*" (IP03)
h. (Negative) work culture and attitudes leads to inaccessibility to information and data	"*Nobody wants to share the data… everybody who has the data he is the boss*" (IP06)	Indifference becomes a normative attitude.	"*Union Government itself doesn't want to share. … let them have their information shared. …with the State… it should be freely available… they have the main role and the initiative has to come from them.*" (IP05)
i. (Negative) work culture and attitudes lead to weak coordination	"*Every director of different departments have ego clashes… stops the whole integration process*" (NG26)	Unwillingness to cooperate with other institutions and sectors.	"*that officers attitude 'I am the boss' has to go*" (IP03)
j. (Negative) work culture and attitude leads to low implementation of adaptation actions	"[*The*] *typical mind-set is that 'my job is secured and I do not need to do anything' kind of attitude. The lack of dedication*" (NG22)	Indifferent attitude by some government officials leading to negligence	"*Government should make some statutory authority… whatever they plan, …should be implemented and there must be some sincere and honest efforts for delivering.*" (IP02)
k. (Negative) work culture and attitude leads to resources limitations	"*There must be some sincere and honest efforts for delivering. Only then, can this be achieved*" (IP02)	Inefficient utilisation of existing human resources	"*The government has to act first what they are saying*" (NG25)
l. Geographical challenges leads to unavailability of information and data	"*because of geographical reason also, we have problem in forecasting…*" (RI21)	Difficulties due to geophysical conditions	"*I think we really need to go in a GIS solutions which can quickly give you some answers*" (SG11)
m. Geographical challenges hinders implementation of adaptation actions	"*Due to physiographic factor like sloppy terrain we cannot go for good water harvesting structure so that is a challenge to this region*" (RI21)	Overall infrastructural development being more difficult in the mountainous region	
n. Limitations in resources leads to a work culture and attitude which is apathetic to the challenges	"*He angrily asked me, 'can't you see that I am the only one here? Tell the Director to give me other supporting staffs. How can I be the only one to collect data from field, monitor and analyse?'*" (NG25)	Demotivation due to lack of adequate resources	"*Allot them some money and some targeted work. Let them come out up to one year, two year or three year some innovative adaptation methodologies*" (RI24)
o. Limitations in resources also leads to unavailability of information and data	"*Research work is not a priority. We do not want to invest in these things because the results are not discernible*" (IP08)	Limited resources allocated for immediate needs than investing for understanding long term impacts.	"*The Centre should stop giving directions to the States. Rather they should give funds with accountability. This will help the state government to plan according to their needs*" (NG25)
p. Weak inter-institutional network leads to systemic and governance challenges	"*All the departments have appointed the nodal officers but later on if we ask them he is either transferred or not there*" (SG09) "*There is no linkage between various departments…, strategies are not evolved in an integrated way or holistic way*" (RI22)	Changes of responsibilities, when not communicated to other agencies, disrupts the system of monitoring and follow up.	"*People need to understand each other first and then come out with some common strategies and this sector is still not explored much. …they need to understand each other's operational aspects and where we can intervene with each other. So that's still required.*" (RI24)
q. Weak inter-institutional network leads to inaccessibility to the existing information and data	"*should set up a nodal agency which can coordinate with different organisations. So that everybody… can exchange views …*[and] *data, what steps, what contingent plans we need to adopt and how we implement it*" (IP03)	Different agencies are unable to access and share information, data and perspectives due to weak inter-institutional networks	"*We must understand… how the other related sectors are influencing us or we are influencing them…. If this understanding comes then second step is coming together like people are coming and create certain infrastructure and then if we have the money and there is a team of good workers who can work together*" (RI24)
r. Weak inter-institutional network leads to low implementation of adaptation			

(continued on next page)

Table 2 (*continued*)

Causes and interconnections	Quotes from interview	Implications	Suggested enablers
actions			
s. Resources limitation leads to low implementation	"*The State Centre on Climate Change for the want of funds couldn't do good projects*" (RI24)	The lack of adequate resources hinders implementation	"*So in my view, first is the money, good team of workers and identification of inter-sectorial problems*"(RI24)
t. Systemic and governance challenges leads to negative work culture and attitude	"*In the system you have so many bottlenecks. That, at the end of the day you'll say, just forget it*" (NG18)	Challenges due to day to day system of functioning	"*Meeting after every six months or three months has no meaning. …Let the Nodal Agency have some money and come up with some targets and then assess those targets. Not otherwise.*" (RI24)
u. Unavailability of information and data leads to limitations in knowledge capacity	"*We don't have a very robust data. We are still groping in the dark*" (SG11)	Ability to understand the system constrained due to lack of information and data	"*I think one should go for proper data base.*" (IP01) "*use Open Data Kits which could reduce both costs and labour*" (NG25)
v. Information and data inaccessibility and unavailability leads to low implementation of adaptation actions	"*Nothing can be done if they don't give you the data*" (NG25) "*You have to tell them about the gravity of the situation. That you won't be able to tell unless and until you have some concrete data, some facts with you*" (IP06)	Implementation is constraint when the required information and data are limited or unavailable	"*There should be a mechanism for direct involvement. We should be able to communicate directly with the specific agency. Data sharing should be a routine job*" (IP08)
w. Information and data unavailability leads to creation of systemic and governance challenges	"*The departments which are supposed to collect basic data are not able to do it. Therefore all these plans and strategies are pretty much hypothetical*" (NG25)	Governance decisions are influenced by the quality and availability of information and data	
x. Weak inter-institutional networks leads to low knowledge capacity	"*The inter-sectorial linkages, that's very week…. We must understand… how the other related sectors are influencing us or we are influencing them*" (RI24)	Oblivious of the interconnected challenges	"*People need to understand each other first and then come out with some common strategies and this sector is still not explored much*" (RI24)

other Indian State governments that led to the formulation of State Action Plan in 2012, in advance of many other States. However, leadership at the implementation level is not apparent due to insufficient allocation of resources, State administrative and governance structures and a lack of motivation for implementation. For example, the Nodal Officers in each State Government department, who are expected to lead the climate actions in their respective departments, are neither empowered nor provided with adequate resources to implement adaptation measures. They are not inspired or motivated to initiate proactive adaptation related activities such as acquiring additional information and knowledge or actively participate and contribute towards identification of potential climate change risks and planning mitigative measures. Moreover, since many are hierarchically subordinate in their department's administrative structure, they are unable to make departmental commitments to any decisions made at the State level meetings convened by the State Centre for Climate Change actions at which they represent their department.

Many State Government officials, including some Nodal Officers, assume that actions related to climate change are the responsibility of the Department of Environment, Science and Technology (DEST): "*Only the DEST can do about this. …We attend meetings whenever DEST calls for meeting*" (SG14). This assumption leads to inadequate participation that rarely go beyond attending, or sending a representative to seminars and workshops convened by DEST. This was evident from their limited involvement in the formulation of the Action Plan document itself:

> "*It was started by DEST and then we had one meeting. They have given us a few questionnaires and what is to be done and how it is to be done and the kind of information to gather and generate. …We have one meeting and then the second meeting unfortunately I was not there. We had only two meetings*" (SG23).

Interviewees felt that the Action Plan is yet to empower action. The Action Plan incorporated a list of potential adaptation strategies identified and proposed by IPH but does not define responsibilities for planning and implementation (leading to a lack of ownership and leadership) nor allocated specific resources, so that it is "*more of a wish list*" (SG11) and the proposed actions remain unfulfilled: "*But they are not on to the ground right now. They are just in the papers*" (IP08). The IPH believes they have fulfilled their responsibility by submitting the potential adaptation strategies, whereas the State Centre assumes that the onus for implementation lies with the relevant departments; in this instance IPH.

The lack of ownership and leadership leads to an institutional system that de-incentivises proactive learning and acquisition of knowledge in general and climate change related knowledge in particular:

> "*As of today there are no such budgets* [for research] *in my department …. Neither there is any assurance nor there any encouragement. So whosoever is doing at his level there is no contribution from the government side.*" (IP02).

3.3.3. Governance, bureaucratic and institutional structure and management processes

Barriers related to effective coordination and accessibility to information and data are closely intertwined with the bureaucratic and institutional structure and management processes (Table 2: d, e and f). For example, a respondent pointed to the governance in the State in general as a practical challenge to implement adaptation actions:

> "*As far as climate change is concerned, governance of climate change is one of the big challenges which has not been addressed particularly in Himalayan region. Governance means initiatives of the government, rules and regulation. Governance indicators are one is accountability, transparency, effectiveness, responsibility, corruption. These are the issues which have to be addressed*" (RA22).

On the other hand, a Nodal Officer attributed the challenges of effective communication with other institutions to the bureaucratic process of routing every communication through the Head of Department:

> "*The most and the biggest challenge is the communication gap. Because the communication challenge is so big that day to day coordination becomes just impossible. … I have to go first from bottom to top in my organization and then from top to bottom in their organization*" (IP08).

Likewise, another respondent suggested that the silo attitude which hinders effective coordination (Section 3.3.6) is due to governance

structure: "[*The*] *Co-ordination problem is always there because of the way current governance structures are. There is a compartmentalised way of thinking and that comes from governance structures*" (NG19). Due to the perceived weaknesses in the governance and institutional structure a respondent proposed to address the challenge of fragmentation and overlapping responsibilities by integrating various departments:

> "*…integrated watershed programme has to be started with the coordination of various departments headed by a single agency. For example, mid-Himalayan watershed programme, … they are doing their work but… independent*[*ly*]*… DRDA* [District Rural Development Agency] *in isolation, Forest department is doing it in isolation, Water resource department in isolation. Why not integrate all these departments?*" (RA22).

The inaccessibility of available data is also largely attributed to bureaucratic and institutional protocols (Table 2: e) that lead to an apparent disconnect between the Central Government agencies operating in the State and the State Government departments:

> "*Central Government… organizations like the Central Water Commission, IMD* [India Meteorology Department], *etc. will not give the data easily. … They should start sharing the data with the state because we are in the same geographical area. … The data sharing policy has been changed recently. But actually it should be freely available until and unless you have some defence interest*" (IP06).

However, a respondent from one of these Central Government agencies replied:

> "*Whenever they ask data we are providing them. Some format and procedure is there of how to get these data. We are just seeing the justification. Anybody can ask* [for] *the data but based on the requirement and the study for which they want to get the data and we provide the data on nominal charges*" (CG12).

Some respondents believe that part of the reason for this apparent mismatch of perspectives is either that they are not confident of their own data or indifferent towards the needs of other institutions: "*One is that everybody thinks that who has the data is the boss.*" (IP06). This respondent described the problem with an example:

> "*I may not be very confident about the quality of my data whether it is correct or not. If I validate my data with some other organisation or some other data I may find my data to be totally wrong. That is another reason I don't want it to share. Whatever I have is ok. It is a common phenomenon everywhere. So this definitely is a challenge*" (IP06).

The same respondent also explained that even formal arrangements like having memorandum of understanding does not ease the difficulty adequately:

> "*… in our organization also we had memorandum of understanding, with various other organizations for sharing of the data. But despite of this actual transfer of data is not smooth. You have to make real efforts to get these kinds of information.*" (IP06).

As described in Section 3.3.2, the Nodal Officers do not have the administrative power to make departmental commitments or decisions so that, in most cases, they passively represent their respective departments: "*They sent their representatives. They said they will consult with the higher authorities and then let you know* [their] *views, their stand or comments on these*" (SG09).

The vaguely defined role of Nodal Officers, the regular transfer of personnel without an effective system of transition and the failure to manage staff succession hinders project continuity, loses the opportunity for organisational learning and maturity and creates a communication gap. For example, an interviewee described the challenges of acquiring information or feedback regarding adaptation strategy formulation and implementation:

> "*Actually people get transferred.* [When] *Nodal Officers change … we have to explain everything to the new person again. It depends upon whether he is taking interest in it or not. In government departments transfer is* [*a*] *major difficulty. We have asked the departments to appoint their nodal officers but many of them are retired or changed or transferred.*" (SG09).

3.3.4. Electoral politics, power struggles and competing priorities in resources allocation

The governance challenges of climate change adaptation in the State also relate to electoral politics. A respondent stated that "*the problem remains with the politicians*" (IP03) and "*excessive democracy*", by which the respondent meant excessive political activism by the general public which interferes with resource allocation. This respondent explained: "*Because it is a democratic country … every MLA* [Member of (State) Legislative Assembly], *every Pradhan* [village chief] *wants the work to be done in their constituency*" (IP03) and "*In a democracy you have to please the voters.*" (SG09). Therefore, the competing priorities and electoral politics lead to a fragmented approach whereby the limited resources are distributed widely to various areas and sectors which leads to inadequacy of resources (Section 3.3.6); "*there is no dearth of money but the problem is it is so thinly spread that everyone is saying "ok sir we don't have money". [The] question is not the lack of money. [A] lot of money is available. But it is just spreading has to be avoided.*" (IP03). When asked about the challenges of implementing the State Action Plan, a respondent replied that "*The first challenge is, as I said, economic development of the state.*" (SG09).

Secondly, issues of power struggles and conflicts over sharing resources within and between government institutions with overlapping activities were reported by respondents. This leads to fragmentation of resources in which the same or similar projects are being implemented by different departments:

> "*Here every department does everything. What happens is we are from IPH. We are doing rainwater harvesting structures, Agriculture Department is also doing it, even the Soil Conservation Department is doing it. The Block Development Department is doing it. … So many agencies are involved. … In typical government departments, no one wants to see that as a specialisation. Because no one wants leave the power.*" (IP03).

This fragmented approach to implementation, intensified by electoral politics, as discussed above, leads to an inefficient funding allocation reducing the capacity to implement larger projects (Table 2: g):

> "*because I wanted to please everyone, it is a political system, so I will give thirty rupees to you and thirty rupees to you and thirty rupees to him. So none of the projects, … cost*[ing] *hundred rupees… will be able to complete.*" [IP03].

Additionally, it creates conflicts:

> "*This is my area. The Forest will say you can't work in my area. The Block will say no. Even I will say Water Supply scheme is my area, so I won't allow you. …What I want, the Block Development will do something else. I want* [*a*] *water supply scheme. But Block Development will simply take away the water from the upstream for the irrigation purpose.*" (IP03).

As a consequence, some respondents suggested making water a Central Government subject, indicating dissatisfaction with the current water governance in the State, although this is often prompted by inter-State water disputes. To avoid these tensions between different sectors and institutions, respondents suggested (Table 2: d) "*there should be a nodal department*" (IP01) to allocate both natural and financial resources or "*… a centralised agency at the district level or may be even at the sub-division level. It should approve that.*" (IP03).

3.3.5. Public engagement and a trust deficit

A weak relationship between the government departments and non-governmental organisations (NGO) is apparent, with many of the respondents from government institutions not trusting the motives of the NGOs:

> "*The problem with NGOs is about 75 to 80% of the NGOs are just interested in money. Only a very few NGOs really work*" (IP03) and "*The current pattern is that there are some three-four NGOs who are there in almost every forum. In every meeting you will find them, very good orators and they are acting in a way as though representing the whole community – lakhs* [hundred thousand] *of people which is not true*." (IP06).

On the other hand, many NGOs believe that the government agencies are not sincerely implementing the adaptation policies and schemes and raise doubts regarding the government data on which policies are based: "*The departments which are supposed to collect basic data are not able to do it. Therefore, all these plans and strategies are pretty much hypothetical*" (NG25). Another NGO respondent stated that government institutions usually only seek inputs from NGOs and other stakeholders to fulfil the criteria of engaging all stakeholders:

> "*For the sake of participation they put it on the website 'Those who would like to contribute can contribute in the next fifteen days or so'. There was hardly any consultation. They took one or two NGOs and specialists from this organization and that organization and they prepared that. So naturally there was not much of input at that time. When it was released a lot of people got interested into that and they saw that a lot of things were missing in that*" (NG26).

As a consequence, there is often a mismatch between the wishes of the general public and the government's provision:

> "*So there is a gap in between. I mean to say the government is not interested to involve all stakeholders. If they involve stakeholders… they will ask questions and they don't want to involve them…. They want to give only that awareness which will serve their purpose. … That is the mismatch between the government and the people. The government is not aware about the issues of the people*." (NG27).

3.3.6. Implementation and follow up mechanisms

Formulation and implementation of new Government strategies or policies are very different challenges. The State Action Plan is weakened by the lack of mechanisms for implementation and monitoring, in addition to barriers discussed previously. When asked how the Action Plan is being implemented, respondents pointed out that "*we don't have any implementing authority*" (RA24), dismissed it as a "*wish list*" (SG11) and stated (Table 2: b) "*The research is being done… but who is the implementing authority? Who is the user of those technologies*?" (RA24), indicating the absence of an institutional mechanism to implement and monitor the proposed Action Plan as a key reason for non-implementation.

Some respondents linked this to the political leadership not being serious enough to put their own policies into actions leading to a disconnection between policy and implementation (Table 2: f) "*See there is no connect between the documentation bit and the ground level bit. There is no connection*" (NG18). On the other hand, some respondents even used strong words such as "*corruption*" (RA22), "*incompetence, lack of professionalism and dedication*" (NG25), on the part of implementing (government) agencies, to describe the root causes of barriers for effective adaptation, for example, pointing out the inconsistency between the actual implementation and the documented records: "*we found that so many check dams were put in files only*" (RA22).

4. Discussion

The responses from various governmental and non-governmental institutions in this study demonstrate complex challenges of adapting water management to climate change in a developing economy with rapidly changing socio-economic conditions and competing priorities for infrastructure development. These additional challenges make it more difficult to translate awareness of the changing climate into tangible adaptation (Eisenack et al., 2014) and illustrates that awareness of the changing climate does not necessarily lead to adaptation actions in contrast to Marshall et al. (2013). This study demonstrates that the path from awareness and acceptance of climate change to adaptation planning, implementation and successful outcomes is a long and winding one. It requires overcoming many barriers and encounters various challenges and crosses paths with other non-climatic challenges that are shaped by socio-economic and political factors as much as by geographical features. The findings in this study corroborates earlier studies (Amundsen et al., 2010; Biesbroek et al., 2014a, 2014b; Eisenack et al., 2014) that posited the potential linkages between institutional factors and adaptation barriers and illustrates that that adaptation to climate change for water management has to take into account these various socio-economic and cultural factors.

The barriers identified in this study are not unique to Himachal Pradesh (e.g. Biesbroek et al., 2013; Islam et al., 2014; Jantarasami et al., 2010; Sciulli, 2013). However, this study shows that the occurrence, emergence, and persistence of adaptation barriers are contextual, dependent on the socio-economic and cultural factors and dynamic (Eisenack et al., 2014), and thus can emerge from different factors in different contexts. For example, lack of financial resources is reported across studies on barriers (Biesbroek et al., 2013; Moser and Ekstrom, 2010), but arises in developed economies from the inability of local agencies to articulate budgetary requirements for adaptation (Eisenack et al., 2014), overall austerity measures (Porter et al., 2015), the lack of legal financial autonomy for the local authorities to acquire financial resources from lending agencies (Crabbé and Robin, 2006), to climate scepticism among councillors (Baker et al., 2012;Engle, 2012). However, in Himachal Pradesh, the fragmented approach of splitting the financial allocation to all sectors, issues and locations based on public pressure, such that each ended up with an inadequate budget, was a key factor compounded by the overall economic condition and competing priorities for short-term developmental activities; thereby pointing to a departure from the causes prevalent in high income countries.

Adaptation barriers due to normative behaviours and indifferent attitudes by specific actors within the implementing agencies are rarely mentioned in other cases (Baker et al., 2012; Burch, 2010; Shemdoe et al., 2015). This study illustrates that indifference and apathy to the potential climate risks, in spite of the acceptance that climate might be changing, can be due to socio-cultural normative behaviours in addition to low knowledge capacity. The lack of knowledge regarding adaptation options also breeds an indifferent attitude that 'nothing can be done'. Lack of implementing agencies, inaccessibility to appropriate information and trust deficiency between different agencies are also cited as common barriers in other developing economies such as Chile (Clarvis and Allan, 2013). Other overwhelming issues and competing priorities can also lead to staff apathy and indifference to the potential risks (Bierbaum et al., 2013; Klein and Smith, 2003; Picketts, 2014). However, awareness raising of potential climate change risks needs to be accompanied by building human capacity and allocation of financial resources and instituting organisational arrangements for implementation of identified strategies with follow-up mechanisms. Therefore, this study illustrates the need for taking into consideration the contextual socio-economic and cultural backgrounds of the region while studying the adaptation barriers and points to the

need to go beyond general institutional design principles for successful adaptation (Oberlack, 2016).

Recent studies have shown that policy paralysis can occur both due to the unavailability of scientific knowledge (Hanger et al., 2013) and the inability of the demand side to access the available knowledge (Archie et al., 2014; Dilling et al., 2015). Making the scientific knowledge accessible to and usable by policy makers and practitioners requires close interaction between the suppliers and users of knowledge. However, an emphasis on the need for more research can also arise from an unwillingness of policy makers to act on a particular issue, citing lack of sufficient evidence (Gardiner, 2011; Oreskes, 2004). The UK Government invested in policy-focussed adaptation science to overcome the informational access and cognitive barriers (Porter et al., 2015) associated with the 'climate information usability gap' (Dilling and Lemos, 2011). However, adaptation did not follow as expected due to other barriers including institutional fragmentation, lack of visionary leadership and statutory adaptation obligations and inadequate budgetary allocations (Porter et al., 2015). This suggests that improving the production and dissemination of usable knowledge, such as through the National Mission on Strategic Knowledge for Climate Change (MST, 2010) in India, will have to be accompanied by additional reforms such as overcoming the inter-related barriers associated with institutional fragmentation, bureaucratic processes, and socio-cultural attitudes.

The issues of power struggles between different agencies and institutions over the sharing and distribution of both natural and financial resources is a challenge that is hindering adaptation implementation at the ground and local level. When financial resources are diversified, they become inadequate for undertaking costly and large adaptation measures. But here the barrier of adaptation becomes subjective depending on the goal of adaptation (Adger et al., 2009). Overlapping of responsibilities is not only resource inefficient but also leads to conflicts of interests within and between government institutions themselves which should be avoided. This overlapping of activities and yet poor coordination between the various institutions operating in the same geographical area is a common challenge in developing economies (Spires et al., 2014) and is largely a governance issue.

Overcoming the identified constraints in Himachal Pradesh, such as lack of technically skilled staff and other resources to address climate change challenges (ADB, 2010), will require collaboration with institutions operating beyond the State as the assumption that adaptation is the responsibility of local bodies is being questioned (Nalau et al., 2015). Moreover, additional financial resources often come from the Central Government or other external agencies. Hence, understanding the vertical interaction with the Central Government or other agencies operating at different scales will provide additional knowledge regarding enabling adaptation (Chaffin et al., 2016; Juhola and Westerhoff, 2011). Therefore, further studies to understand the role of institutions operating beyond the State agencies such as the Central Government agencies are required for formulating enabling mechanisms of adaptation.

5. Conclusion

Climate change is an additional driver of change to the pre-existing challenges of meeting increasing water demand due to population growth, economic development and land use changes in developing countries. This research has enriched the understanding of the causes and inter-dependencies of barriers to climate change adaptation for water management institutions in a complex top-down bureaucratic system of governance involving multiple sectors and institutions competing over limited resources. It has identified and highlighted the importance of under-acknowledged aspects of adaptation barriers, including socio-normative attitudes of implementing agencies and the influence of a democratic governance on short term priorities at the expense of long-term strategic issues. This study has also empirically substantiated an otherwise largely theoretical understanding that barriers are interconnected and demonstrated how barriers emerge and persist in particular contexts by exploring their root causes. Consequently, the contextual significance of adaptation barriers need to be taken into consideration while framing adaptation policies to enable the identification of intervention leverage points that maximise barrier removal, thereby contributing to achieving a better adapted society.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.scitotenv.2016.10.151.

Acknowledgements

We acknowledge the Government of India (grant no. 11016/10/2010) for sponsoring this research, the UK Irrigation Association for the Jack Wright Travel Scholarship and the UK Natural Environment Research Council (grant number NE/1022329/1) for supporting the fieldwork. We are also grateful to Mr. Ian Truckell for preparing the map in Fig. 2. Finally, the authors thank the interviewees for their time and valuable contributions. The funding agencies have no involvement in the design of the study or interpretation of the result. Enquiries regarding the data generated should be sent to researchdata@cranfield.ac.uk

The following is the supplementary data related to this article.

References

ADB, 2010. Climate Change Adaptation in Himachal Pradesh: Sustainable Strategies for Water Resources. Asian Development Bank Available at. http://www.adb.org/sites/default/files/publication/27999/cca-himachal-pradesh.pdf (Last accessed on 02/09/2016).

Adger, W.N., Arnell, N.W., Tompkins, E.L., 2005. Successful adaptation to climate change across scales. Glob. Environ. Chang. 15:77–86. http://dx.doi.org/10.1016/j.gloenvcha.2004.12.005.

Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D.R., Naess, L.O., Wolf, J., Wreford, A., 2009. Are there social limits to adaptation to climate change? Clim. Change 93:335–354. http://dx.doi.org/10.1007/s10584-008-9520-z.

Amundsen, H., Berglund, F., Westskogh, H., 2010. Overcoming barriers to climate change adaptation-a question of multilevel governance? Environ. Plann. C. Gov. Policy 28: 276–289. http://dx.doi.org/10.1068/c0941.

Archie, K.M., Dilling, L., Milford, J.B., Pampel, F.C., 2014. Unpacking the "information barrier": comparing perspectives on information as a barrier to climate change adaptation in the interior mountain west. J. Environ. Manag. 133:397–410. http://dx.doi.org/10.1016/j.jenvman.2013.12.015.

Baker, I., Peterson, A., Brown, G., McAlpine, C., 2012. Local government response to the impacts of climate change: an evaluation of local climate adaptation plans. Landsc. Urban Plan. 107:127–136. http://dx.doi.org/10.1016/j.landurbplan.2012.05.009.

Barnett, J., Evans, L.S., Gross, C., Kiem, A.S., Kingsford, R.T., Palutikof, J.P., Catherine, M., 2015. From barriers to limits to climate change adaptation: path dependency and the speed of change. Ecol. Soc. 20. http://dx.doi.org/10.5751/ES-07698-200305.

Bedsworth, L.W., Hanak, E., 2010. Adaptation to climate change. J. Am. Plan. Assoc. 76: 477–495. http://dx.doi.org/10.1080/01944363.2010.502047.

Berkhout, F., 2012. Adaptation to climate change by organizations. Wiley Interdiscip. Rev. Clim. Chang. 3:91–106. http://dx.doi.org/10.1002/wcc.154.

Bierbaum, R., Smith, J.B., Lee, A., Blair, M., Carter, L., Chapin III, F.S., Fleming, P., Ruffo, S., Stults, M., McNeeley, S., Wasley, E., Verduzco, L., 2013. A comprehensive review of climate adaptation in the United States: more than before, but less than needed. Mitig. Adapt. Strateg. Glob. Chang. 18, 361–406.

Biesbroek, G.R., Klostermann, J.E.M., Termeer, C.J.A.M., Kabat, P., 2013. On the nature of barriers to climate change adaptation. Reg. Environ. Chang. 13, 1119–1129.

Biesbroek, G.R., Termeer, C.J.A.M., Klostermann, J.E.M., Kabat, P., 2014a. Rethinking barriers to adaptation: mechanism-based explanation of impasses in the governance of an innovative adaptation measure. Glob. Environ. Chang. 26:108–118. http://dx.doi.org/10.1016/j.gloenvcha.2014.04.004.

Biesbroek, G.R., Termeer, C.J.A.M., Klostermann, J.E.M., Kabat, P., 2014b. Analytical lenses on barriers in the governance of climate change adaptation. Mitig. Adapt. Strateg. Glob. Chang. 19:1011–1032. http://dx.doi.org/10.1007/s11027-013-9457-z.

Brenkert, A.L., Malone, E.L., 2005. Modeling vulnerability and resilience to climate change: a case study of India and Indian states. Clim. Chang. 72:57–102. http://dx.doi.org/10.1007/s10584-005-5930-3.

Bisaro, A., Hinkel, J., Kranz, N., 2010. Multilevel water, biodiversity and climate adaptation governance: evaluating adaptive management in Lesotho. Environ. Sci. Policy 13: 637–647. http://dx.doi.org/10.1016/j.envsci.2010.08.004.

Bryant, A., 2014. The grounded theory method. In: Leavy, P. (Ed.), The Oxford Handbook of Qualitative Research. Oxford University Press, Oxford, pp. 116–136.

Burch, S., 2010. Transforming barriers into enablers of action on climate change: insights from three municipal case studies in British Columbia, Canada. Glob. Environ. Chang. 20:287–297. http://dx.doi.org/10.1016/j.gloenvcha.2009.11.009.

Chaffin, B.C.C., Garmestani, A.S.S., Gosnell, H., Craig, R.K.K., 2016. Institutional networks and adaptive water governance in the Klamath River Basin, USA. Environ. Sci. Policy 57:112–121. http://dx.doi.org/10.1016/j.envsci.2015.11.008.

Clarvis, M.H., Allan, A., 2013. Adaptive capacity in a Chilean context: a questionable model for Latin America. Environ. Sci. Pol. 43:78–90. http://dx.doi.org/10.1016/j.envsci.2013.10.014.
Crabbé, P., Robin, M., 2006. Institutional adaptation of water resource infrastructures to climate change in eastern Ontario. Clim. Chang. 78:103–133. http://dx.doi.org/10.1007/s10584-006-9087-5.
DEST-HP, 2012. State Strategy & Action Plan on Climate Change. Department of Environment, Science & Technology, Government of Himachal Pradesh, Shimla Available at. http://desthp.nic.in/publications/HPSCCAP_A1b.pdf (Last accessed on 03/09/2016).
Dilling, L., Lackstrom, K., Haywood, B., Dow, K., Lemos, M.C., Berggren, J., Kalafatis, S., 2015. What stakeholder needs tell us about enabling adaptive capacity: the intersection of context and information provision across regions in the United States. Weather. Clim. Soc. 7:5–13. http://dx.doi.org/10.1175/WCAS-D-14-00001.1.
Dilling, L., Lemos, M.C., 2011. Creating usable science: opportunities and constraints for climate knowledge use and their implications for science policy. Glob. Environ. Chang. 21:680–689. http://dx.doi.org/10.1016/j.gloenvcha.2010.11.006.
Dow, K., Berkhout, F., Preston, B.L., 2013. Limits to adaptation to climate change: a risk approach. Curr. Opin. Environ. Sustain. 5:384–391. http://dx.doi.org/10.1016/j.cosust.2013.07.005.
Eisenack, K., Moser, S.C., Hoffmann, E., Klein, R.J.T., Oberlack, C., Pechan, A., Rotter, M., Termeer, C.J.a.M., 2014. Explaining and overcoming barriers to climate change adaptation. Nat. Clim. Chang. 4:867–872. http://dx.doi.org/10.1038/nclimate2350.
Eisenack, K., Stecker, R., 2012. A framework for analyzing climate change adaptations as actions. Mitig. Adapt. Strateg. Glob. Chang. 17:243–260. http://dx.doi.org/10.1007/s11027-011-9323-9.
Engle, N.L., 2012. Adaptation bridges and barriers in water planning and management: insight from recent extreme droughts in Arizona and Georgia. J. Am. Water Resour. Assoc. 48:1139–1150. http://dx.doi.org/10.1111/j.1752-1688.2012.00676.x.
Fidelman, P.I.J., Leitch, A.M., Nelson, D.R., 2013. Unpacking multilevel adaptation to climate change in the Great Barrier Reef, Australia. Glob. Environ. Chang. 23: 800–812. http://dx.doi.org/10.1016/j.gloenvcha.2013.02.016.
Finger, M., Tamiotti, L., Allouche, J., 2006. The Multi-Governance of Water: Four Case Studies. State University of New York Press.
Fünfgeld, H., 2010. Institutional challenges to climate risk management in cities. Curr. Opin. Environ. Sustain. 2, 156–160.
Gardiner, S.M., 2011. A Perfect Moral Storm: The Ethical Tragedy of Climate Change. Oxford University Press, USA.
Graneheim, U.H., Lundman, B., 2004. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse Educ. Today 24:105–112. http://dx.doi.org/10.1016/j.nedt.2003.10.001.
Hanger, S., Pfenninger, S., Dreyfus, M., Patt, A., 2013. Knowledge and information needs of adaptation policy-makers: a European study. Reg. Environ. Chang. 13:91–101. http://dx.doi.org/10.1007/s10113-012-0317-2.
IPCC, 2014. Summary for policymakers. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York http://dx.doi.org/10.1007/BF02986817.
IPCC, 2012. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 3–21.
Islam, M.M., Sallu, S., Hubacek, K., Paavola, J., 2014. Limits and barriers to adaptation to climate variability and change in Bangladeshi coastal fishing communities. Mar. Policy 43:208–216. http://dx.doi.org/10.1016/j.marpol.2013.06.007.
Jantarasami, L.C., Lawler, J.J., Thomas, C.W., 2010. Institutional barriers to climate change adaptation in U.S. national parks and forests. Ecol. Soc. 15.
Jaswal, A.K., Bhan, S.C., Karandikar, A.S., Gujar, M.K., 2015. Seasonal and annual rainfall trends in Himachal Pradesh during 1951–2005 study area which lies in the western Himalayas, bounded by Jammu. Mausam 2, 247–264.
Jiménez Cisneros, B.E., Oki, T., Arnell, N.W., Benito, G., Cogley, J.G., Döll, P., Jiang, T., Mwakalila, S.S., 2014. Freshwater resources. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., M., D.M., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., M., S., Mastrandrea, P.R., W., L.L. (Eds.), Climate Change 2014: Impacts, Adaptation and Vulnerability — Contributions of the Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 229–269.
Juhola, S., Westerhoff, L., 2011. Challenges of adaptation to climate change across multiple scales: a case study of network governance in two European countries. Environ. Sci. Pol. 14:239–247. http://dx.doi.org/10.1016/j.envsci.2010.12.006.
Klein, R.J.T., Midgley, G.F., Preston, B.L., Alam, M., Berkhout, F.G., Dow, K., Shaw, M.R., 2014. In: Field, C.B., Barros, V.R., Dokken, D.J., K.J. (Eds.), Adaptation Opportunities, Constraints, and Limits, in: Climate Change: 2014 Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge and New York, pp. 899–943.
Klein, R.J.T., Smith, J.B., 2003. Enhancing the capacity of developing countries to adapt to climate change: a policy relevant research agenda. Climate Change, Adaptive Capacity and Development, pp. 317–334.
Krysanova, V., Dickens, C., Timmerman, J., Varela-Ortega, C., Schlüter, M., Roest, K., Huntjens, P., Jaspers, F., Buiteveld, H., Moreno, E., de Pedraza Carrera, J., Slámová, R., Martínková, M., Blanco, I., Esteve, P., Pringle, K., Pahl-Wostl, C., Kabat, P., 2010. Cross-comparison of climate change adaptation strategies across large river basins in Europe, Africa and Asia. Water Resour. Manag. 24:4121–4160. http://dx.doi.org/10.1007/s11269-010-9650-8.
Lebel, L., Garden, P., 2008. Deliberation, Negotiation and Scale in the Governance of Water Resources in the Mekong Region. In: Pahl-Wostl, C., Kabat, P., Möltgen, J. (Eds.), Adaptive and Integrated Water Management Coping with Complexity and Uncertainty. Springer, pp. 205–225.
Mall, R.K., Gupta, A., Singh, R., Singh, R.S., Rathore, L.S., 2006. Water resources and climate change: an Indian perspective. Curr. Sci. 90:1610–1626. http://dx.doi.org/10.1016/S0143-8166(02)00004-0.
Marshall, N.A., Park, S., Howden, S.M., Dowd, A.B., Jakku, E.S., 2013. Climate change awareness is associated with enhanced adaptive capacity. Agric. Syst. 117:30–34. http://dx.doi.org/10.1016/j.agsy.2013.01.003.
Mertz, O., Halsnæs, K., Olesen, J.E., Rasmussen, K., Halsnaes, K., Olesen, J.E., Rasmussen, K., 2009. Adaptation to climate change in developing countries. Environ. Manag. 43: 743–752. http://dx.doi.org/10.1007/s00267-008-9259-3.
Mills, J., Bonner, A., Francis, K., 2006. The development of constructivist grounded theory. Int. J. Qual. Methods 5:25–35. http://dx.doi.org/10.2307/588533.
Moser, S.C., Ekstrom, J.A., 2010. A framework to diagnose barriers to climate change adaptation. Proc. Natl. Acad. Sci. U. S. A. http://dx.doi.org/10.1073/pnas.1007887107.
Mollinga, P.P., Dixit, A., Athukorala, K., 2006. Integrated water resources management: global theory, emerging practice, and local needs, Water in South Asia. SAGE Publications http://dx.doi.org/10.2166/wst.2010.262.
MST, 2010. Mission document of national mission on strategic knowledge for climate chnage (RPRT). Ministry of Science & Technology, Government of India, New Delhi Available at. http://dst.gov.in/sites/default/files/NMSKCC_July_2010.pdf (last accessed on 13/10/2016).
Nalau, J., Preston, B.L., Maloney, M.C., 2015. Is adaptation a local responsibility? Environ. Sci. Pol. 48:89–98. http://dx.doi.org/10.1016/j.envsci.2014.12.011.
Oberlack, C., 2016. Diagnosing institutional barriers and opportunities for adaptation to climate change. Mitig. Adapt. Strateg. Glob. Chang. http://dx.doi.org/10.1007/s11027-015-9699-z.
Oreskes, N., 2004. Science and public policy: what's proof got to do with it? Environ. Sci. Pol. 7:369–383. http://dx.doi.org/10.1016/j.envsci.2004.06.002.
Pahl-Wostl, C., 2009. A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. Glob. Environ. Chang. 19:354–365. http://dx.doi.org/10.1016/j.gloenvcha.2009.06.001.
Picketts, I.M., 2014. Practitioners, priorities, plans, and policies: assessing climate change adaptation actions in a Canadian community. Sustain. Sci. 10:503–513. http://dx.doi.org/10.1007/s11625-014-0271-7.
Pittock, J., 2011. National climate change policies and sustainable water management: conflicts and synergies. Ecol. Soc. 16.
PMCCC, 2008. National Action Plan on Climate Change, Prime Minister's Council on Climate Change, Government of India. New Delhi, India.Available at. http://www.moef.nic.in/downloads/home/Pg01-52.pdf (Last accessed on 03/09/2016).
Porter, J.J., Demeritt, D., Dessai, S., 2015. The right stuff? Informing adaptation to climate change in British local government. Glob. Environ. Chang. 35:411–422. http://dx.doi.org/10.1016/j.gloenvcha.2015.10.004.
Preston, B.L., Westaway, R.M., Yuen, E.J., 2010. Climate adaptation planning in practice: an evaluation of adaptation plans from three developed nations. Mitigation and Adaptation Strategies for Global Change. Springer, Netherlands http://dx.doi.org/10.1007/s11027-010-9270-x.
Rana, R.S., Singh, S., Chander, N., Sood, R., Himachal, C.S.K., Agricultural, P., 2014. Impacts of changes in climate on mountain water resources of Himachal Pradesh. Mausam 2, 153–160.
Richards, L., 1999. Using NVivo in Qualitative Research. SAGE Publications, New Delhi http://dx.doi.org/10.1017/CBO9781107415324.004.
Roggero, M., 2015. Adapting institutions: exploring climate adaptation through institutional economics and set relations. Ecol. Econ. 118:114–122. http://dx.doi.org/10.1016/j.ecolecon.2015.07.022.
Saldana, J., 2009. The Coding Manual for Qualitative Researchers, The Coding Manual for Qualitative Researchers. Los Angeles, London, New Delhi, Singapore, Washington DC. http://dx.doi.org/10.1109/TEST.2002.1041893.
Sciulli, N., 2013. Organizational barriers to adapting infrastructure assets to climate change: evidence from coastal councils in Australia. Public Money Manag. 33: 153–160. http://dx.doi.org/10.1080/09540962.2013.763436.
Shackleton, S., Ziervogel, G., Sallu, S., Gill, T., Tschakert, P., 2015. Why is socially-just climate change adaptation in sub-Saharan Africa so challenging? A review of barriers identified from empirical cases. Wiley Interdiscip. Rev. Clim. Chang. 6:321–344. http://dx.doi.org/10.1002/wcc.335.
Shemdoe, R., Kassenga, G., Mbuligwe, S., 2015. Implementing climate change adaptation and mitigation interventions at the local government levels in Tanzania: where do we start? Curr. Opin. Environ. Sustain. 13:32–41. http://dx.doi.org/10.1016/j.cosust.2015.01.002.
Spires, M., Shackleton, S., Cundill, G., 2014. Barriers to implementing planned community-based adaptation in developing countries: a systematic literature review. Clim. Dev. 6:277–288. http://dx.doi.org/10.1080/17565529.2014.886995.
Strijbos, J.W., Martens, R.L., Prins, F.J., Jochems, W.M.G., 2006. Content analysis: what are they talking about? Comput. Educ. 46:29–48. http://dx.doi.org/10.1016/j.compedu.2005.04.002.
Tang, Z., Dai, Z., Fu, X., Li, X., 2013. Content analysis for the U.S. coastal states' climate action plans in managing the risks of extreme climate events and disasters. Ocean Coast. Manag. 80:46–54. http://dx.doi.org/10.1016/j.ocecoaman.2013.04.004.
Wilby, R.L., Wood, P.J., 2012. Introduction to adapting water management to climate change: putting our science into practice, Area. 44:394–399. http://dx.doi.org/10.1111/j.1475-4762.2012.01133.x.